PATENT SPECIFICATION 821,668

DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

An Arrangement for Producing a Variable Colour Lighting Effect.

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to an arrangement for producing a variable colour lighting effect suitable for decorative lighting, advertising, or like purposes.

For producing such an effect the invention makes use of the known phenomenon of electrophoresis, whereby a mixture of two gases in an elongated electric discharge tube operated on direct current tends to separate, with the gas of the lower ionisation potential drifting towards the cathode and the gas of higher ionisation potential drifting towards the anode.

This effect is sometimes observed with low-pressure mercury vapour fluorescent electric discharge lamps having a mercury and argon filling, when operating on direct current, the mercury gradually drifting towards the cathode end of the lamp. The effect is then regarded as a disadvantage, since it results in the lamp appearing bright only at the cathode end, and for avoiding it the lamp operating circuit may be provided with a switch for periodically reversing the polarity of the connection of the lamp electrodes to the supply before any effect due to electrophoresis becomes noticeable. Since such a lamp always contains excess mercury, a considerable time, usually at least several hours, of operation is required to produce the effect at normal room temperatures and the switch need be operated only at correspondingly long time intervals.

[*Price* 3*s.* 6*d.*]

If, however, a filling of two different rare gases is used, with one at a relatively low partial pressure compared with the partial pressure of the other, the separation of the gases by electrophoresis takes place much more quickly, in a matter of minutes or even seconds rather than hours, and this fact is made use of by the invention, together with the further facts that the colours and/or intensities of the visible radiations emitted by electric discharges through different rare gases are different and that such discharges also emit ultra-violet radiation capable of exciting fluorescent materials.

According to one aspect of the invention an arrangement for producing a variable colour lighting effect includes an elongated electric discharge tube provided at each end with an electrode arrangement capable of acting either as an anode or as a cathode, having a rare gas filling containing at least two different rare gases at such relative partial pressures as to be separable by electrophoresis in operation of the tube on direct current, and including fluorescent material excitable by the passage of an electric discharge through the rare gases, the tube being in combination with circuit components arranged for operating the tube from a direct current supply, said components including a switch arranged when operated to reverse the polarity of connection to the supply of the electrode arrangement at each end of the tube, and the rare gases and fluorescent material being chosen so that in operation of the tube in one polarity of connection to the supply, after separation of the rare gases by electrophoresis has taken place the colour of the resultant light emitted from one end of the tube is different from that emitted from the other end of the tube, and on reversal of

the polarity of connection of the tube to the supply, and after interchange of the positions of the rare gases by electrophoresis has taken place, the colour of the resultant light changes at least at one end of the tube.

The term " resultant light " means the light resulting from combination of the primary visible radiation from the electric discharge passing through the rare gas filling at the corresponding end of the lamp with the fluorescent light resulting from excitation of the fluorescent material by ultra-violet radiation from the discharge. Where, as might sometimes be the case, no fluorescent material is provided at one end of the lamp, the resultant light is simply the primary visible radiation from the discharge. In some cases the primary visible radiation might be of such intensity as to swamp the fluorescent light, in which case the resultant light is of practically the same colour as the primary visible radiation, or in other cases the primary visible radiation might be so weak that the resultant light is of practically the same colour as the fluorescent light. By a suitable choice of rare gases and fluorescent materials several different colour effects and colour changes can be obtained.

It is to be observed that most fluorescent materials excitable by a low-pressure mercury discharge are also excitable to some extent by a discharge through a rare gas, and since for display purposes luminous efficiency is not usually an important factor, and since also the primary light from discharges through rare gases other than neon are not very intense, most of these known fluorescent materials are usable in arrangements in accordance with the invention.

The choice of fluorescent materials to be used will, of course, depend on the nature of the filling components used and on the colour effects required.

The following table gives, by way of example, the resultant colour obtainable with some combinations of rare gas at low pressure with two fluorescent materials of particular interest :—

Rare gas.	Intensity and colour of primary radiation.	Resultant light with willemite	Resultant light with calcium tungstate.
Neon	Strong red	Amber	Pink
Xenon	Weak blue	Green	Blue
Argon	Weak mauve	Green	Blue
Krypton	Weak pale blue	Green	Blue
Helium	Moderate cream or ivory	Pale green	White

Cadmium borate, calcium silicate, magnesium arsenate, magnesium germanate, zinc tungstate, magnesium tungstate, and calcium magnesium silicate, are examples of other fluorescent materials which might be used in arrangements in accordance with the invention.

It will be understood that the above nomenclature refers to the activated forms of the compounds in question where activation is required.

When the colour change effect is required to take place in rapid sequence, as might be required for advertising purposes, the switch controlling it can be arranged to be operated automatically, consisting for example of an electromagnetic switch, the time interval between successive operations of the switch being sufficiently long to permit separation of the rare gases by electrophoresis to take place.

The invention includes within its scope the provision of electric discharge tubes especially designed for use in an arrangement of the kind described. Such tubes contain a filling of at least two rare gases separable by electrophoresis, preferably at a total pressure of not more than about 50 millimetres mercury and usually between 2 and 10 millimetres mercury, with the partial pressure of one gas being less than 1 millimetre mercury and preferably a small fraction, for example 0.1%, of the partial pressure of the other ; the tubes are provided at each end with an electrode capable of acting either as an anode or as a cathode, and include fluorescent material whose composition or distribution is non-uniform along the length of the tubes so as to be differently excited by the passage of a unidirectional electric discharge through the rare gas filling according to the direction of the discharge.

While, in a tube for use in an arrangement according to the first aspect of the invention, the fluorescent material might consist of the same material coated uniformly over the whole of the internal surface of the tube between the electrodes, preferably the tube is

of the kind described above, and might be coated with a different material at each end, possibly with a clear space separating the two materials or with the intervening space coated with a third material excitable by the discharge or merely light-diffusing. In other cases it might be desirable for the fluorescent material(s) to be included other than as a coating on the tube surface; for example for advertising purposes it might be required to include the material(s) as coatings on letter forms mounted within the tube.

Preferably the electrodes are of the "hot-cathode" type, consisting of tungsten coils coated with activating material and having anode plates attached to the electrode supports, as used in ordinary fluorescent lamps designed for operation on mains voltages, but alternatively electrodes of the "cold-cathode" type, consisting of hollow iron or nickel cylinders as used in high-tension fluorescent lamps, might be used.

A particularly suitable combination for use in accordance with the invention is neon and xenon for the gas filling components, and willemite and calcium tungstate for the fluorescent materials.

One tube which makes use of this combination will now be described by way of example. The tube has a tubular glass envelope about 5 feet long and 1½ inches diameter coated internally over a length of about 2 feet from one end with willemite and coated internally over a similar length from the other end with calcium tungstate. The lamp is provided at each end with "hot-cathode" electrodes of the activated double-coil type provided with anode plates attached to the electrode supports, the electrodes being carried on pinched foot-tubes closing the tubular envelope, in the usual manner. The gas filling within the tube envelope consists of neon together with about 0.1% by volume of xenon at a total filling pressure of about 5 mm. mercury.

When the tube is operated at 500 milliamps from a direct current supply with the willemite-coated end as cathode, the xenon drifts to this end and a bright green resultant light is obtained, the primary light from the xenon being of such low intensity that the resultant light is mainly the fluorescent light from the willemite.

The neon drifts to the anode end of the tube and here the red light from the neon and blue light from the calcium tungstate provide a resultant pinkish light.

On reversal of the polarity of connection of the tube electrodes to the supply, the neon drifts to the willemite-coated end of the tube to produce an orange or amber resultant light, depending on the current density of the discharge, whilst the xenon drifts to the calcium-tungstate-coated end to produce a blue resultant light.

By periodically reversing the polarity of the electrode connections, for example using an automatically operated electromagnetic switch, an attractive colour change sequence can be obtained.

The circuit arrangement for operating a tube of the kind just described will, usually, include a ballast resistance and a starting inductor in series with the tube, together with a starting switch connected across the tube.

It will, however, be appreciated that in some cases the tube might be operated on an alternating supply having a strong direct component instead of on an ordinary direct current supply.

WHAT WE CLAIM IS:—

1. An arrangement for producing a variable colour lighting effect including an elongated electric discharge tube provided at each end with an electrode arrangement capable of acting either as an anode or as a cathode, having a rare gas filling containing at least two different rare gases at such relative partial pressures as to be separable by electrophoresis in operation of the tube on direct current, and including fluorescent material excitable by the passage of an electric discharge through the rare gases, the tube being in combination with circuit components arranged for operating the tube from a direct current supply, said components including a switch arranged when operated to reverse the polarity of connection to the supply of the electrode arrangement at each end of the tube, and the rare gases and fluorescent material being chosen so that in operation of the tube in one polarity of connection to the supply after separation of the rare gases by electrophoresis has taken place the colour of the resultant light emitted from one end of the tube is different from that emitted from the other end of the tube, and on reversal of the polarity of connection of the tube to the supply, and after interchange of the positions of the rare gases by electrophoresis has taken place, the colour of the resultant light changes at least at one end of the tube.

2. An arrangement according to Claim 1 wherein at least part of the discharge tube envelope is coated internally with willemite, or calcium tungstate, or cadmium borate, or calcium silicate, or magnesium arsenate, or germanate, or zinc tungstate, or magnesium tungstate, or calcium magnesium silicate, fluorescent material.

3. An arrangement according to Claim 1 wherein one part of the discharge tube envelope is coated internally with willemite fluorescent material and another part is coated internally with calcium tungstate fluorescent material.

4. An arrangement according to Claim 1, 2 or 3 wherein the rare gases present in the discharge tube envelope are neon at a rela-

tively high partial pressure and xenon at a relatively low partial pressure, the total pressure being less than 50 millimetres mercury.

5. An arrangement according to any preceding claim including switch operating means arranged automatically to reverse the polarity of the electrode connections at time intervals sufficiently long to permit separation of the rare gases by electrophoresis to take place.

6. An electric discharge tube suitable for use in an arrangement according to any preceding claim, having a tubular envelope containing a filling consisting of two or more rare gases separable by electrophoresis, provided at each end with an electrode capable of acting either as an anode or as a cathode, and including fluorescent material whose composition or distribution is non-uniform along the length of the tube so as to be differently excited by the passage of a unidirectional electric discharge through the rare gas filling according to the direction of the discharge.

7. An electric discharge tube according to Claim 6 wherein the rare gas filling consists of neon and xenon and the fluorescent material consists of willemite or of calcium tungstate, or of both willemite and calcium tungstate arranged at different regions along the length of the envelope.

8. An electric discharge tube according to Claim 7 wherein one end part of the tube envelope is coated internally with willemite fluorescent material and the other end part is coated internally with calcium tungstate fluorescent material.

9. An electric discharge tube according to Claim 7 or 8 wherein the partial pressure of the neon lies between 2 and 10 millimetres mercury and the partial pressure of the xenon is less than 1 millimetre mercury.

10. An electric discharge tube according to Claim 9 constructed as hereinbefore described by way of example.

For the Applicants :—
J. E. M. HOLLAND,
Chartered Patent Agent.

PROVISIONAL SPECIFICATION.

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This effect is sometimes observed with low-pressure mercury vapour fluorescent electric discharge lamps having a mercury and argon filling, when operating on direct current, the mercury gradually drifting toward the cathode end of the lamp. The effect is then regarded as a disadvantage, since it results in the lamp appearing bright only at the cathode end, and for avoiding it the lamp operating circuit is usually provided with a switch for periodically reversing the polarity of the connection of the lamp electrodes to the supply before any effect due to electrophoresis becomes noticeable. Since such a lamp always contains excess mercury, a considerable time, usually at least several hours, of operation is required to produce the effect and the switch need be operated only at correspondingly long time intervals.

If, however, a filling of two different rare gases is used, with one at a relatively low pressure compared with the pressure of the other, the separation of the gases by electrophoresis takes place much more quickly, in a matter of minutes or even seconds rather than hours, and this fact is made use of by the invention, together with the further facts that the colours and/or intensities of the visible radiations emitted by electric discharges through different rare gases are different and that such discharges also emit ultra-violet radiation capable of exciting fluorescent materials.

According to one aspect of the invention an arrangement for producing a variable colour lighting effect includes an elongated electric discharge tube provided at each end with an electrode arrangement capable of acting either as an anode or as a cathode, having a rare gas filling containing two different rare gases at such relative pressures as to be separable by electrophoresis in operation of the tube on direct current, and including fluorescent material excitable by the passage of an electric discharge through the rare gases, the tube being in combination with circuit components arranged for operating the tube from a direct

current supply, said components including a switch arranged when operated to reverse the polarity of connection to the supply of the electrode arrangement at each end of the tube, and the rare gases and fluorescent material being chosen so that in operation of the tube in one polarity of connection to the supply, after separation of the rare gases by electrophoresis has taken place the colour of the resultant light emitted from one end of the tube is different from that emitted from the other end of the tube, and on reversal of the polarity of connection of the tube to the supply, and after interchange of the positions of the rare gases by electrophoresis has taken place, the colour of the resultant light changes at least at one end of the tube.

The term "resultant light" means the light resulting from combination of the primary visible radiation from the electric discharge passing through the rare gas filling at the corresponding end of the lamp with the fluorescent light resulting from excitation of the fluorescent material by ultra-violet radiation from the discharge. Where, as might sometimes be the case, no fluorescent material is provided at one end of the lamp, the resultant light is simply the primary visible radiation from the discharge. In some cases the primary visible radiation might be of such intensity as to swamp the fluorescent light, in which case the resultant light is of practically the same colour as the primary visible radiation, or in other cases the primary visible radiation might be so weak that the resultant light is of practically the same colour as the fluorescent light. By a suitable choice of rare gases and fluorescent materials several different colour effects and colour changes can be obtained.

It is to be observed that most fluorescent materials excitable by a low-pressure mercury discharge are also excitable to some extent by a discharge through a rare gas, and since for display purposes luminous efficiency is not usually an important factor, and since also the primary light from discharges through rare gases other than neon are not very intense, most of these known fluorescent materials are usable in arrangements in accordance with the invention.

The choice of fluorescent materials to be used will, of course, depend on the nature of the filling components used and on the colour effects required.

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Argon	Weak mauve	Green	Blue
Krypton	Weak pale blue	Green	Blue
Helium	Moderate cream or ivory	Pale green	White

Cadmium borate, calcium silicate, magnesium arsenate, magnesium germanate, zinc tungstate, magnesium tungstate, and calcium magnesium silicate, activated in known manner where necessary, are examples of other fluorescent materials which might be used in arrangements in accordance with the invention.

When the colour change effect is required to take place in rapid sequence, as might be required for advertising purposes, the switch controlling it can be arranged to be operated automatically, consisting for example of an electromagnetic switch, the time interval between successive operations of the switch being sufficiently long to permit separation of the rare gases by electrophoresis to take place.

The invention includes within its scope the provision of electric discharge tubes especially designed for use in an arrangement of the kind described. Such tubes contain a filling of at least two rare gases separable by electrophoresis, preferably at a total pressure of not more than about 50 millimetres mercury and usually less than 10 millimetres mercury, with the pressure of one gas being a small fraction, for example 0.1%, of the pressure of the other ; the tubes are provided at each end with an electrode capable of acting either as an anode or as a cathode, and include fluorescent material excitable by the passage of an electric discharge through the rare gas filling.

In some cases the fluorescent material might consist of the same material coated uni-

formly over the whole of the internal surface of the tube between the electrodes. In other cases the tube might be coated with a different material at each end, possibly with a clear space separating the two materials or with the intervening space coated with a third material excitable by the discharge or merely light-diffusing. In yet other cases it might be desirable for the fluorescent material(s) to be included other than as a coating on the tube surface; for example for advertising purposes it might be required to include the material(s) as coatings on letter forms mounted within the tube.

Preferably the electrodes consist of heatable tungsten coils coated with activating material and having anode plates attached to the electrode supports, as used in ordinary fluorescent lamps designed for operation on mains voltages, but alternatively cold, i.e. non-heatable, electrodes might be used, such as the electrodes used in high-tension fluorescent lamps.

A particularly suitable combination for use in accordance with the invention is neon and xenon for the gas filling components, and willemite and calcium tungstate for the fluorescent materials.

One tube which makes use of this combination will now be described by way of example. The tube has a tubular glass envelope about 5 feet long and $1\frac{1}{2}$ inches diameter coated internally over a length of about 2 feet from one end with willemite and coated internally over a similar length from the other end with calcium tungstate. The lamp is provided at each end with activated double-coil electrodes provided with anode plates attached to the electrode supports, the electrodes being carried on pinched foot-tubes closing the tubular envelope, in the usual manner. The gas filling within the tube envelope consists of neon together with about 0.1% by volume of xenon at a total filling pressure of about 5 mms. mercury.

When the tube is operated at 500 milliamps. from a direct current supply with the willemite-coated end as cathode, the xenon drifts to this end and a bright green resultant light is obtained, the primary light from the xenon being of such low intensity that the resultant light is mainly the fluorescent light from the willemite.

The neon drifts to the anode end of the tube and here the red light from the neon and blue light from the calcium tungstate provide a resultant pinkish light.

On reversal of the polarity of connection of the tube electrodes to the supply, the neon drifts to the willemite-coated end of the tube to produce an orange or amber resultant light, depending on the current density of the discharge, whilst the xenon drifts to the calcium-tungstate-coated end to produce a blue resultant light.

By periodically reversing the polarity of the electrode connections, for example using an automatically operated electromagnetic switch, an attractive colour change sequence can be obtained.

The circuit arrangement for operating a tube of the kind just described will, of course, include a ballast resistance for the tube, and possibly also an electrode-heating transformer, which is desirable but not essential, and a starting switch. It will, however, be appreciated that the invention is applicable with high-tension tubes having cold electrodes as well as with tubes having heatable electrodes.

It will also be appreciated that in some cases the tube might be operated on an alternating supply having a strong direct component instead of on an ordinary direct-current supply.

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